DOCUMENT RESUME

ED 138 292 IR 004 722

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TITLE Procurement Policy in CAI Systems. Illinois Series in Educational Application of Computers. No. 21.
PUB DATE Feb 77
NOTE 21p.

EDRS PRICE MF-$0.83 HC-$1.67 Plus Postage.
DESCRIPTORS Administrative Policy; *Computer Assisted Instruction; Computer Oriented Programs; *Decision Making; Educational Specifications; Guidelines; *Policy; *Program Costs; *Purchasing; Secondary Schools

ABSTRACT

The use of computers for both administrative and/or instructional activities in secondary schools is increasing. In acquiring, maintaining, and expanding computer resources, decisions must be made regarding both products and services. This report identifies the issues and concerns related to procurement policy decisions, and guidelines are given for addressing each of the identified concerns. (DAG)

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Number 21

The Illinois Series on

Educational Applications of Comupters

Procurement Policy in CAI Systems

Viktors J. Kuiznieks

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February 1977

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IR004 732

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INTRODUCTION

Background Information

The use of computers for both administrative and/or instructional activities in the secondary schools is rapidly becoming a reality. In 1966, a public survey reported that only 181 of 11,000 schools surveyed used computers in their instructional activities. By 1970, the results of an American Institute for Research (AIR) study indicated that 34.5% of 12,396 secondary schools surveyed were using computers for some kind of administrative and/or instructional purposes (of which 12.9% was solely for instructional purposes); this same computer usage figure rose to 54.7% in 1975 (with 24.6% of the total reflecting instructional uses).**1

The marked increase in computer use which is prevalent outside of the educational field, coupled with the observation that the cost of computer equipment is declining while the number, variety, and capabilities of modern day mini- and micro- computers is increasing, indicates that the trend in computer use in schools will also continue to rise. In order to effectively integrate computer systems into various school functions, some means for determining which of the myriad of computer systems, computer languages, and computer services that are available best fit the needs of individual institutions.

In acquiring, maintaining, and expanding computer resources, school administrators, teachers, and consultants will be forced into making decisions regarding what products and/or services need to be procured for the schools' use. They will, in effect, be formulating procurement policy. In so doing they will need some basis for forming their decisions, and some structure which can be used in identifying, outlining, and organizing the requirements of their particular school environments.

For the purposes of this paper, a CAI system and a procurement policy will be defined in the following ways:

A CAI system is generally composed of computer-related equipment, resource personnel, and user groups; various interactions occur among and between the resource personnel and user groups which effect not only the CAI system itself, but also the more general educational system of which the CAI system is only a part. Anyone who uses or is effected by one or more components within a CAI system is considered to be a part of that CAI system.

Procurement policies are specific actions which result in the acquisition, modification, or elimination of equipment, supplies, or personnel within the CAI system. Such policies are generally aimed at furthering the 'common good' of those within the system, and are generally used to determine 'who gets what' in the system.**2

It is often the case that procurement policy decisions in CAI systems must be made by resource personnel who are not familiar with computer technology. This paper is primarily written for the administrators and teachers who will be involved in such decision-making processes. Attempts are made to identify the issues and concerns related to procurement policy decisions, and guidelines are given for addressing each of the identified concerns. The applicability of this paper, however, is not limited to the secondary school audience; many of the ideas and principles discussed can be applied by any individual, organization, or institution involved in the formulation of procurement policy.

Key Question Specification

The key question being addressed in this paper is:

How should procurement policy be formulated?

The answer to this question is explored by trying to identify the factors that relate to the formulation of procurement policy, and categorizing the specific areas of concern for each of the factors involved in the policy formation process.

The basic contention of this paper is that the formulation of procurement policy is intimately related to an analysis of desired system performance characteristics based on specific system performance factors. Exactly what these characteristics and factors are will be defined in the discussion that follows.

SYSTEM PERFORMANCE MODEL

Overview of Model

One purpose of this paper is to present a model which will not only identify certain factors that can be used in measuring and evaluating a CAI system's performance, but which will also indicate methods for formulating policies dealing with the procurement and expansion of CAI systems in general. It would be far too presumptuous to suppose that all of the factors involved in the acquisition and evaluation of a CAI system could be neatly identified, classified, and summarized; yet it would not be too unrealistic to imagine the existence of a model which could be used to relate many of them in a clear, concise, and constructive way.

The model chosen for this study is the result of applying a model regarding policymaking and system performance in general, to CAI systems in particular #43 (see Figure 1). The way the model works is that four separate areas have been identified which can directly influence policy decisions. These areas are the needs, demands, goals, and costs of the system. Usually (although this may not always be the case) the needs present in the system cause demands to be placed upon the system. In order for the demands to be met, goals must be established. In order to reach the goals set for the system, policies need to be formulated. Policies, however, are affected not only by the system goals, but by cost considerations as well. These cost considerations are often independent of the needs, demands, and goals of the system.

In using this model, system performance is not to be measured by system output alone. The relationships between system output and the various components regulating the system - needs, demands, goals, and costs - are what determine system performance. This paper will not attempt to try to define all of the elements which determine the goals, needs, costs, and demands of a CAI system. Rather, it will concentrate on the factors which relate these components to the system output, while at the same time providing some insight about the general nature of the elements themselves. The factors to be considered will be called fidelity, responsiveness, effectiveness, and efficiency.

Trying to operate a CAI system is often exceedingly difficult because of the contradictory nature of the system performance factors. Tradeoffs are often required, and the success or failure of overall system performance is often dependent upon decisions involving the balancing of two or more of these factors.

Fidelity

Fidelity is a measure of how well the system output corresponds to the needs of those in the system. It is, in a general sense, a measure of how well the system responds to societal values and principles. One of the more prominent of these is equality in education, or at least the removal of inequalities of educational opportunity. In order for a system to possess fidelity, the system must be able to determine what the needs of its constituency are, how those needs are likely to change, how well it is fulfilling those needs, and what it has to do in order to better satisfy those needs. Difficulties arise not only in determining what those needs are, but also how they change and how best to monitor them.

In order to assure that system fidelity is obtained, it is important that the societal needs relating to the proposed system are recognized and stated. These could be expressed as a need for an educated citizenry or a need for qualified manpower for the economy, but usually they will relate directly to a CAI environment. These will be the needs that have given rise to the demands placed upon the system.

Responsiveness

In order for a system to be considered responsive, it must have the capacity to change and reflect the demands placed upon it by groups or individuals. This is a political problem which requires the adjusting of output to meet the demands. Closely associated with this factor is the problem of communication within the system.

Any system which fails to respond to the demands placed upon it will quickly lose support from the effected constituents. For example, a system that fails to give quick response to a user requesting assistance in getting some equipment repaired or to another user requesting off-line documentation of a specific program is running the risk of alienating those users. Of course, no system can possibly satisfy all of the demands placed upon it, yet every system will be forced into making decisions that ultimately effect everyone involved within the system.

In order to measure how responsive a system really is, which issues have been and are being dealt with, and which groups receive what kind of treatment, interviews or survey procedures could be employed, with specific sample groups being determined within each individual system.

Effectiveness

Once the needs and demands of the system are understood, goals can be formulated which are aimed at meeting those demands. The effectiveness of the system is the degree to which the system output approaches explicitly stated goals. The goals of a CAI system may include the production of computer programmers capable of writing BASIC programs, or the introduction of students to problems related to privacy and security in computer systems handling large data files.

It is unfortunate that such goals are often rather vaguely stated (if present at all), so that before the effectiveness of the system can be measured, a determination of the goals must also be made. After that, the system output still has to be measured to find the extent to which goals are fulfilled. It might be very beneficial to try to determine the criteria which could be used to measure how well goals are achieved at the same time the goals themselves are formulated, so that some basis for determining the effectiveness of the system is present.

It is also a good idea to establish priorities for the goals, since this will make later decisions easier to justify. This will also help reduce the problem of decreasing emphasis on a goal to make the system appear more effective, i.e. any time emphasis placed on a non-fulfilled goal is decreased, system effectiveness is increased. Only then should the more difficult problems associated with system efficiency and responsiveness be undertaken, since then there is also a framework upon which to base decisions; also, only after the goals have been established should the problem of getting as much as possible of whatever is needed at a reasonable cost be considered.

Efficiency

In a general sense, the concept of efficiency involves the ratio of cost to what is produced. Efficiency is always increased if more is produced at the same cost, or if the same amount is produced at a lower cost, i.e. efficiency can be visualized as output/cost($). The total cost of a CAI system can be fairly well determined if accurate budget records and expenditure listings are kept. The monetary equivalent of the output produced by the system is generally a much harder quantity to estimate. It is clear that in a system designed to produce good computer programmers, adopting a policy which requires spending less money, yet which produces the same number of equally good programmers, has resulted in a system that has a greater efficiency, since the cost term in the ratio has decreased while the output term has remained unchanged. If, however, the policy change had resulted in the production of more programmers who were not as good as the previous ones (in whatever way that is determined), then the comparison is not as simple, because it is difficult to place monetary equivalents on items such as programmer quality (except possibly as a function of salary).

What usually happens is that cost and output have to be adjusted to a point which gives the most favorable ratio between the two within a specified range of values, using a rather arbitrary scale for measuring the system output. Indeed, the choice of scale for measuring the output may produce different efficiency calculations based on the various factors considered and the relative weights assigned to them.

Hence what often happens is that decisions have to be based upon estimated or expected values, and a discrepancy between the actual efficiency of the system and the perceived efficiency of the system can result. For example, a decision for acquiring more terminals based on the evidence that currently owned terminals are being used 98% of the time may be justifiable if users are actually working at the terminals for all of that time. However, if the 98% figure is based on a system-measured connect-time for the computer and the terminals, then it conceivably could be the case that the terminals are actually physically attached to the system while no productive work is being done for as much as 20% of the measured connect-time. Hence the perceived efficiency of the system may differ from the actual efficiency of the system by as much as 20%.

SYSTEM PERFORMANCE FACTORS AND PROCUREMENT POLICY

Overview

Each of the various system performance factors identified relates to procurement policy in its own way. There are specific attributes of the system which should be considered when making procurement policy decisions. The following sections will deal with each factor separately, and try to highlight the areas of procurement policy to which each factor is most applicable.

Of course, many of the topics discussed can and do pertain to the domain of several of the factors. In such cases, attempts are made to place the topics into the discussion of the factor which is most directly related to the area in question. Sometimes, the implications which the topic has for other factors are also mentioned. For example, the topic 'the number of users' is listed under responsiveness even though it has separate effects upon the efficiency and effectiveness factors of the system as well.

By addressing all of the issues raised in relation to each system performance factor, guidelines for establishing system policy will emerge. The issues raised and topics discussed are intended to focus attention upon the various elements in the system which are pertinent to the formation of procurement policies. If careful consideration is given to each topic area, then the resulting procurement policy should produce a system which possesses fidelity, responsiveness, effectiveness, and efficiency.

Fidelity Considerations

The attributes of a CAI system which can be related to fidelity are the following***4:

--the needs of the community of users
--the composition of the intended user groups
--the nature of the subject matter being taught
--the role of the computer in the school's mission
--the direction the school is taking
--the long range plans of the school

The needs of the community of users should be one of the first problems addressed. Without an understanding of what the users of the system need, no basis for justifying decisions about what products or services to procure can be made. As discussed in the previous section on fidelity, these needs should not only be those that relate specifically to CAI, but also those that relate to society in general. Attention should be paid to identifiable concerns which are being expressed by groupings within the user community.

The composition of the intended user group is another important concern. It is necessary to assess the age and ability levels of those being served by the CAI system. In particular, there is a need to look for deficiencies such as physical handicaps or poor reading or arithmetic skills which might later restrict the usefulness of some computer equipment or programming languages. Similarly, looking for existing competencies in the intended audience which might be put to good use by some particular devices or languages is equally important.

Examples of how these considerations might be used are the following. Exceptional typing skills might indicate that programs should be written using terminals or keypunches rather than by using mark-sensed cards. Fluency in the use of algebraic techniques might indicate that it would be beneficial to use a language like APL (A Programming Language). If the students are blind, then it may be necessary to use a braille printer or some sort of audio device; or if the concept of music appreciation is to be taught, some device capable of producing sounds might be required.

The nature of the subject matter being taught should be understood, and reasons ought to be given as to why a CAI system can address the subect matter better than some other system. If such reasons can not be found, perhaps the needs of the users or society will not be met by a CAI system, and some other alternatives should be explored.

The role of the computer in the school's mission will often effect the needs of the human part of the system. If the school is anxious to be at the forefront of technological progress or research, and to effect the state-of-the-art in such fields, the needs of the system will be decidedly different from those of a school that is primarily interested in using previously written programs to supplement instruction and to process information records.

The direction the school is taking is closely related to the role which the computer is expected to play in the school's mission. By determining the direction the school is taking, the acquisition of a computer system can change the direction being taken by expanding or contracting a research program, or increasing or decreasing the activity levels in areas such as science, mathematics, and management. The direction which the school will take should strive towards fulfilling the needs of its users.

What this means is that a CAI system can be used not only to enhance existing school programs, but also to adjust the emphasis on such programs, and even redirect where the emphasis should be placed.

Understanding the institution's long range plans involves identifying the current needs of the system, and projecting how those needs are likely to change within five or ten years. This is important for later decisions involving the kind and amount of computer equipment and services to invest in, and the manner in which those products should be procured.

Responsiveness Considerations

In order for a system to be considered responsive to the demands of its users, it must be able to answer questions dealing with:

--the number of users
--the dispersion of the users
--the envisioned computer uses
--the ease of system expansion
--the expected longevity of the system

The number of users that the system is expected to serve relates to several of the system performance factors. If there are only a few users, it should be relatively easy to recognize, consider, and respond to the demands placed upon the system by each one. In a large system, with many users, it is much more difficult to pay attention to the demands of individual users.

The estimate on the number of users will also effect the throughput, turnaround, and response times expected of the system which are discussed in relation to the system's effectiveness. In addition to this, the efficiency of the system is effected by the number of users in many ways, such as when trying to decide how much storage to get for the system, or what services to offer within the system.

The dispersion of the users becomes very important to any CAI system, and it is essential to recognize whether the demands of the users will include being able to access the computer from one location, from several centrally located points, or from a large number of geographically separated places.

The answer to this question relates directly to efficiency considerations as well. The cost of the communication link between the main computer and various attached devices can often be very expensive for particular types of equipment, so knowing if all the computing activity can be confined to one room, to several adjoining rooms, throughout the building, or among several buildings is of significant importance.

It is necessary to determine the ways in which the computer's use is envisioned in the instructional process, and the relative priorities of those uses. Common instructional techniques employed in CAI include drill and practice, tutorial, problem solving, instructional games, simulation, and dialogue strategies. Common functions associated with computer use include computer-managed instruction (CMI), test construction and grading, and data analysis. Related administrative uses include applications such as scheduling, payroll, and student record storage.

The results of such a study will not only define the demands which will be placed upon the system, but will directly influence the choices of I/O (input/output) media, the main computer itself, the programming languages considered, and the rules and scheduling procedures which will be established for allowing users to gain access to the system.

The possibility of system expansion should always be kept in mind, since no matter how large a system is to begin with, eventually someone will need more of something. Demands will change and good system response will become important. Hence, compatibility with existing equipment and ease of expanding capabilities should continually be kept in mind. Planning ahead is vitally important.

For example, classroom instruction can often be aided by using a TV monitor hooked up to a terminal, so that all the students in the room can see what is going on by viewing the TV screen. The hookup can be easily accomplished with some terminals (CRT's), while being almost impossible with others (teletypes).

Associated with this area is looking for new sources of funds for use with the system. Examples of this might include the selling of time and space to outside agencies during idle periods, or, if working in a school environment, demonstrating the feasibility of using the computer for helping to improve the reading skills of special education students qualified for more state or federal aid.**5 Departments within the school may have special interests which could lead them to expand the resources of the basic system for their own use, such as a guidance department which may want to acquire its own terminal for use with a special program that gives information on colleges, careers, and job opportunities, or an English department trying to improve a remedial reading program.

Throughout the entire decision-making process, the envisioned longevity (expected lifetime) of the system should also be kept in mind, as well as the nature of the system itself. The requirements and demands placed upon a system which is to be a short-lived exploratory probe into the feasibility of acquiring a large-scale system will be considerably different from those of a medium-sized system that is expected to provide computer services for ten years.

The answer to this question will also have an effect upon the way in which the computer services are acquired, as discussed under effectiveness considerations.

Effectiveness Considerations

The effectiveness of a CAI system centers around answers to the following issues:

--the goals of the CAI system
--which computer system to acquire
--what computer languages to use
--which vendor(s) to deal with

Before any procurement policy decisions are made, the goals of the CAI system should be clearly stated. An ordering of the goals by priorities makes decisions easier to justify, and establishes a basis upon which to measure the effectiveness of the system.

Once the goals of the CAI system have been established, the question of which computer system to get can be addressed, based on the relationships between the identified needs and demands of the CAI system and the desired goals.

There are essentially three kinds of computer systems available:

batch processing systems
timesharing systems
single user systems

In a batch processing system, users write programs o
which will be asked by a program, and submit them to
prepared by other users. The computer processes the ent
results. If a program fails to work properly, or if furt
be repeated.

It is often the case that a long period of time may
submitted to the computer and the results are returne
even more time is needed to repeat the process. The lack
machine which this time lag creates is the major drawback

The greatest assets of this kind of computer system
user) than the other two computer systems to be discusse
many users at once.

This type of computer system is most adequate fo
programming. It is not very good for use in areas tha
and machine. (For example, in a drill and practice type
generate problems for students to answer, and be
immediately, so that the student does not have to wait f

In a timesharing system many users can be making re
appears as if each user has complete control over the c
use all of the computer resources for a fraction of a se
great enough so that within the 'time-slice' given to ea
system can be satisfied, and each user will be able to f
computer.

This kind of computer system is very good for inter
communication with the computer for an extended perio
have access to the computer system at any particular tim
a batch processing system can serve).

With the current increase in the number of microcom
alternative of single user systems is also becomi
system, the operation of the entire computer is devoted
interaction for that user is available, even though t
time period is much less than with either of the other t

Generally speaking, for most educational purposes,
batch processing system since it allows for a greater d
the user and the machine, and makes available a greater
machine use in the teaching process. Timeshared syst
can not serve as many users as rapidly as can a batch pr
which offer both capabilities, and are probably the b
advantages of both kinds of computer systems can be inco

Single user computer systems are not very popular
development is occurring, and soon it may be the case
and devoted microcomputers in various departments throus
used for the individual needs of those departments.

There are other considerations which must be taken
These include the questions of whether a large or smal
most appropriate to meet the needs, demands, and goals o
this paper), and also how the following measures
measures are called:

throughput
turnaround time
response time

Throughput refers to the number of people that can
interval; the more people that can be served, the gre
throughput as high as possible in any educational syste
system productivity.

Turnaround time refers to the length of time it tak
request (usually used in conjunction with batch proce
good to have a short turnaround time (less than a second
batch processing system). Sometimes, in an attempt to s
turnaround time of some complex requests must be increas
two factors are often a prime concern in system design
turnaround time with high system throughput.

Response time is the time it takes the machine to r
significant consequences; usually it is disastrous
immediate feedback to drill and practice, demonstration,
thought is easily interrupted and broken. However, i
students capable of doing computer programming, it may
operations are an acceptable approach to take.

An efficient system probably has a high throughput rate; whereas turnaround time and response time can be adjusted to regulate one of the system performance factors in a way which depends on the priorities set for the system.

When trying to decide which language to use; the three most important factors which have already been discussed under fidelity and responsiveness are the instructional strategies to be used; the subject matter to be taught; and the ability levels of the users. Other factors include the equipment needed to implement the language; the adequacy of record keeping capabilities of the language; and the experiences of others who have used the same language.

Languages suitable for the design of tutorial lessons are not always good for producing simulations; nor is a language designed for business applications suited to serve as a lesson-writing medium; a language that is easy enough to be learned by elementary school students may frustrate more advanced high school students.

Some guidelines about the different types of languages available are given; and a classification of the more common computer languages is made in Table 1. Admittedly; some of the languages could be listed under more than one category (in particular BASIC and APL); but attempts are made to place each language into the category which best describes its use.

Table 1: Classification of Computer Languages by Type

COMPUTER DOMINO LANGUAGES

1) DOMINO 2) DOMINO-PC; DOMINO

LEARNING AUTHORING LANGUAGES

1) TUTOR 2) PILOT; 3) COURSEWRITER

SELF MODIFYING LANGUAGES

1) SNOBOL 2) SNOBOL4

PROGRAMMING FREE LANGUAGES

1) INFL 2) PILOT; 3) CAIRS

ASSEMBLY AND MACHINE LANGUAGES

1) ALL MACHINES HAVE THEIR OWN

SCIENTIFIC AND BUSINESS LANGUAGES

1) ALGOL; 2) COBOL; 3) FORTRAN; 4)PASCAL; 5) PL/1

Problem Solving Languages: These languages are usually characterized by an active on-line interaction between the user and the computer. Most of these languages evaluate each statement immediately after it is entered; and inform the user if something is wrong with that statement. The language includes commands to perform standard computations and commands such as inserting a string; reading in parameters from the user; saving; printing; conditional; iterative; and input/output functions; and allowing the user to create and use new functions.

Learning Authoring Languages: These languages not only permit authors to prepare lessons; but also contain additional functions for controlling the interaction between the student and the computer; for example; they may contain commands for branching; for analyzing student responses; for recording student performance; and for displaying text; graphics; and sound. Some of these languages are designed for use by authors who have little or no knowledge of computer programming; while others require a knowledge of programming. Some of these languages are designed for use by authors who have little or no knowledge of computer programming; while others require a knowledge of programming.

Programming-free Languages-these languages are typically supplied as one option in a computer-managed instruction package that also does other things like sequencing student movement through various programs and keeping track of records on students' performance. The languages are designed to aid in the creation of lessons which follow a specific pattern. No programming knowledge is required of the lesson-writer and simply answers questions and sequences units of material in a way that is set up and managed by the computer. Depending on the way in which the questions are answered, a lesson is automatically generated for the user in a programming language acceptable to the computer.

Usually, this form of lesson writing takes a 'cookbook' format, in that the lesson-writer is actually using a program written on the computer, which displays the choices (ingredients) available for creating a lesson, and automatically creates the equivalent computer code to each choice that the lesson-writer makes. (Of course, lesson and course planning are still required before a computer-lesson can be created.)

Assembly and Machine Languages-these languages are available on all machines, and represent the actual operations within the computer; they afford no guidance to the lesson-writer whatsoever. The commands available correspond to specific internal machine operations, which have to be combined to perform even the simplest of tasks. Even though, in theory, the lesson-writer working in these languages has a greater number of commands which can be used to perform a wider range of functions, the increased complexity of use and the greater number of programming statements required to create a lesson tend to discourage authors from using these languages. Actually, all lessons are converted into some form of machine language equivalent before they are executed, regardless of the type of programming language used.

Scientific and Business Languages-these languages were designed to operate in a batch processing, as opposed to time-sharing, mode. They tend to be used for performing sophisticated and accurate calculations on large amounts of data already contained in files, and for the generation of printed reports. Because of the large number of data handling features, and because of the relative ease of programming, these languages are useful for many applications. However, because the interactive computer terminal is designed to operate in a time-sharing mode, the use of these languages in CAI is limited. Some of the more powerful computer languages, such as PL/1, can be used in a time-sharing mode, but require a large computer system to support them.

[illegible] a starting point from which to develop various possible course-language arrangements.

[illegible] for example, figures 21 and 22 give an estimate of the number of programs that could be written in specific languages, and for specific instructional purposes from these figures, conclusions like drill and practice programs may be easier to write in APL and appear to be cheaper on IBM machines might be drawn. However, if the system will be required to provide drill and practice capabilities, an IBM-based APL system might be an alternative to pursue.

There are comparative sources available to aid in the process of choosing specific vendors and computer systems. For example, the OCCE (Oregon Council for Computer Education) has put out a Special Report on 'Microprocessors in Education: Questions, Alternatives, Recommendations, and Related Resources' which contains a description of vendors in the microcomputer field, along with recommendations about each one, including which ones to avoid. Computers and Automation magazine annually publishes 'A Computer Directory and Buyers' Guide.' It contains lists of computer products for sale or rent along with a description of their characteristics. This source is also good for finding installations with similar interests since it provides a listing of computer centers and the machines they use.

Discussions with people who are already using the equipment in question, or who have investigated, the possibility of using similar computer resources are often of invaluable aid in acquiring information on a particular product.

In dealing with vendors it is important to determine the amount of supporting services, in terms of maintenance, repairs and consultation which they offer, as well as the documentation they provide along with their products. An appropriate checklist of questions to ask a vendor might include the following ideas:

Some of these questions have implications which might be obvious at first glance. For example: the presence of a large library of programs may not be very useful if the programs do not do exactly what needs to be done. (After all, how many textbooks are used exactly as they are written?) Hence, the ease with which those programs can be modified to meet the needs of particular applications is also important.

Just because a machine is new is no reason to discard it. It may well be that the new machine is precisely what the system needs. However, in such a case, it is important to realize the need for a well qualified and experienced staff to oversee the system operations, and be available to correct problems when they occur. It is not easy to be a pioneer, but sometimes equipment can be purchased a lot cheaply this way! In the guise of being an experimental system.

Of course, testing the validity of the answers received to the above questions is not an easy task. In fact, there is no 'sure' way of determining whether the answers given are indeed correct. Frequently, however, contacting users of similar systems for discussions in user group meetings) can be helpful in determining which claims are valid. Also, an examination of the buyers' guides discussed above can help substantiate vendor claims. If possible, an examination should be made of printed materials for clarity, readability, and completeness before they are purchased.

Efficiency Considerations

The costs which enter into the efficiency considerations of a system are listed below:

For the most part, once the kind of equipment needed is decided upon, vendors can be contacted, compatibility with existing equipment can be determined, and the specific options desired discussed, so that the model within the desired category chosen best meets the needs of the system.

A few items deserve special attention. For instance, there are various kinds of terminals available. One common distinction often made between terminals is whether or not they provide printed output (hard-copy). Hard-copy terminals tend to operate rather slowly and noisily. However, hard-copy output is usually advantageous for students to take with them after completing a terminal session, and for teachers to look at when grading assignments. One disadvantage that hard-copy terminals naturally have is an ongoing paper supply cost.

Another item which deserves special attention is the matter of compatibility. Many times, a terminal will be built (out of a standard kit) by a hobbyist who is unfamiliar with the RS-232 standard. Or, a terminal may be purchased from a vendor who has not adhered to the standard. In either case, the terminal may not be able to communicate with the computer. Sometimes a few interface changes will correct the problem, but sometimes the terminal will simply not be usable with the computer.

In relating to persons and users of some common systems, various devices are given in lists of the relative costs of the devices. Costs are estimated (they depend, of course, on the specific devices chosen and the options chosen on each device that is desired).

(10)

Table 2: A Comparison of Various Storage Devices. The table is grouped from the fastest to the slowest devices, and the costs of the devices roughly parallel their speeds.**10 The relative speeds are determined by comparing the speed of the device with the speed of a cassette tape. The speed is measured in terms of the number of characters which can be read per second. The speed at which a cassette tape can operate is between 1000 and 10,000 characters per second.

Device	Type	Relative Speed
main memory	on-line	100-100,000 times as fast
disks	usually on-line	10-10,000 times as fast
drums	usually on-line	10-10,000 times as fast
mastape	usually off-line	same-1000 times as fast
cassette tape	usually off-line	base of 1000-10,000 characters per second
cards	off-line	1/100-same times as fast
paper tape	off-line	1/1000-1/10 times as fast

Systems needing on-line storage will probably require either a disk or drum for rapid (within a second) response times. Most systems with a stored library or frequently used lesson materials will probably need this type of storage scheme. If the requirements of the system are such that the program size is usually small, say 1000 characters (75 lines of code) or less, and if there is no necessity for rapid access to stored programs (as in an environment dedicated to teaching students to become computer programmers), cheaper off-line media such as cards or paper tape may be used, and considerable cost savings may be achieved.

Computer equipment may be procured in one of three ways:

---purchase from a vendor
---lease with option to buy
---rental

Equipment can be purchased either fully assembled, tested, and guaranteed, or in kit form (especially for 'microcomputers'). If facilities and expertise exist for the building of computer equipment within the school, considerable cost savings can be realized.

Studies have shown that of the three methods for procuring equipment listed above, purchasing is the best, followed by leasing, and then rental.**11 The findings are based upon lowest cost considerations, and take into account the effects of the leverage which can be exerted upon vendors by withholding payment in order to receive service and support.

Essentially, the basic argument in favor of rental is that computer equipment becomes obsolete quickly, and replacement is easier to accomplish if equipment is rented. This argument does not overpower the fact that considerable cost savings result from purchase and leasing arrangements.

Computer equipment can become obsolete in one of three ways-through physical, technical, or economic obsolescence. By examining each of these types of obsolescence, it becomes clear why the argument in favor of rental is not very strong.

The estimated physical life of various types of computer equipment is the following:**12

main computer	12-16 years
disks and drums	10-14 years
tapes	8-12 years
printer, card reader	8-10 years
various terminals	10-14 years

Hence, the chance of physical obsolescence is not very great.

The argument that the technology is changing rapidly, and that it is constantly improving is no longer as valid as it was several years ago. It is true that the microcomputer industry is changing rapidly, but these are systems that are intended to be purchased and modified as the changes occur. The changes usually effect only the internal speeds of the machine itself (which are close to peak speeds already). The changes do not effect the peripheral devices attached to the system which can account for as much as 90% of the system's cost anyway.**13

Economic obsolescence, where the system no longer meets the needs and requirements of the users effectively, can be minimized by careful planning, constant reevaluation, and applying the techniques discussed in this paper.

If at all possible, CAI equipment should be purchased. If insufficient funds exist, or if maintenance agreements can not otherwise be made, then leasing should be considered. In this way, the most cost-effective system will be procured. Only if no other alternative is available should systems be rented.

The existence of resource personnel can be another critical problem; determination of the preparedness of staff members in programming, operating, maintaining, and using the computer as an instructional resource, as well as in training others to use that resource, is necessary. If no such people are found, the questions of whether such people can be hired, what the salaries of such people will be, and how long it will take them to train others in these uses must also be considered. The release time that teachers will need in order to become trained should be entered into the cost calculation.

User groups (people using the same type of computer, and who get together to exchange ideas and information) can be an important source of resource personnel. Also, nearby Universities can frequently provide assistance and consultation. They can also function as a source of external programming support. (11)

If it is decided to acquire ownership of some system, a very important and often overlooked point is one of maintenance contracts. Too frequently large expenditures are made on equipment, and no allowance is made to guarantee its continued operation and repair. It makes very little sense to spend a lot of money for a system which sits idly by until someone is found who realizes that a fuse is blown or a wire has come loose.

Attention should also be given to establishing means of providing internal communication regarding information related to the system. This might take the form of newsletters, guiding committees, or daily discussions between system personnel and interested parties. It is always wise, whenever possible, to consider using (or employing) students to maintain and operate certain parts of the system (or even to help educate teachers), as well as letting them function as communication links between different places within the system.##14 Other factors which relate to maintenance costs are the ongoing costs of electricity, phone service, and supplies.

If a CAI system already exists, then in conversion to a new system, several additional costs may be incurred. These include the costs of disposing of the current system, reeducating users to become acquainted with the operations of the new system, and converting existing programs and files to work on the new system.

Installation costs including transportation, site preparation, and space acquisition, are important to consider before equipment is actually purchased. An analysis of office space, power requirements, and air-conditioning costs are essential before system installation is possible. It is also important to find out how long it will take to actually receive the equipment once it has been ordered (called lead-time). It is not uncommon for computer equipment to require up to several months to be delivered and installed.

Another aspect of installation considerations involves the desirability of being able to easily move computer equipment. Frequently, it is advantageous to be able to give demonstrations or conduct classes in different rooms throughout a school. Hence, the flexibility (portability) of the system will be important. It is necessary, therefore, to determine if the computer equipment will remain in a fixed location, or if it will be moved around.

Finally, the costs of documentation, including programming and user manuals, as well as guides to the overall system software and hardware should not be neglected. Ongoing documentation costs also occur as programs and lessons become available for use on the system. Such programs should be accompanied by documented materials, and the formation, storage, and dispersal of such materials will increase the cost of the system.

A SIMPLE EXAMPLE

In order to present a situation which could exemplify all of the features of the above model, a rather complex and detailed discussion of a particular CAI system would have to be presented, along with a description of the environment in which it operates. For the purposes of this paper, a simplified example is presented in which only a few of the relevant system and environmental characteristics are discussed. It is hoped that the general idea of how procurement policy can be formulated can be conveyed by treating a few of the areas associated with some of the system performance factors.

As a simple example, consider the common situation where it has been decided that a great enough demand exists to justify the purchase of a card reader for a CAI system. In order to use this card reader, it must be decided whether to procure keypunchable or mark-sensed cards (cards that can be coded using a regular pencil). The vendor from which all of the equipment in the system has been purchased has agreed to supply comparable service and support for whatever kind of card reader is decided upon. The acquisition of the card reader will not effect the programming languages available on the system at this time.

The effectiveness of the system will not be an issue in this process, since the goals of the system will be advanced by acquiring a card reader. The goals of the system include exposing as many students as possible to the computer, and briefly acquainting them with computer uses and limitations. For this purpose, a short term computer literacy unit has been developed. This unit will be included in the course offerings of the social science department.

Fidelity considerations will be dealt with first. The long range plans of the school do not involve using the computer for any sort of administrative record keeping or data analysis activities. Also, the school has no plans for using the machine for research purposes, and there are no distinctive features in the user population which would preclude the use of specific kinds of equipment, or which would rule out the possibility of using any of the devices required for producing mark-sensed or keypunched cards. The need for acquiring a card reader is based upon the fact that the system's throughput is currently too low. The present system is not servicing enough students as it is, and the increased number of users which will result from the addition of the computer literacy units necessitate the acquisition of a card reading (batch) facility.

Responsiveness considerations have also been dealt with. The computer system is currently operating in a timeshared environment, and it has been in existence for two years. The system is expected to remain in the school for many years to come. The computer's use is purely instructional in nature (primarily used for teaching computer science, affording drill-and practice opportunities, and conducting simulation exercises).

There currently are an average of four classes per period trying to use the 6 available terminals (25 students per class, 7 periods per day). The classes are mostly computer programming, computer math, science, business, and foreign language classes. It is hoped that the introduction of the batch processing capabilities will allow the programmers and business people to be serviced in a batch fashion, and that the drill and practice lessons of the foreign language classes could be run on the terminals. The simulations used by the science people could be modified so that answers to simulation questions could be prepared beforehand, and a class run made in a batch fashion. This would require the preparation of detailed handouts.

All of the computing activity is centered around a very small room next to the mathematics department office.

The cost considerations which affect the system's efficiency are the following. In order to have mark-sensed cards printed, a plate must be designed showing the desired card layout. There is an initial production cost associated with the preparation of this plate, as well as a time investment in designing it.

In order to have keypunched cards, noisy and expensive keypunches must be purchased, and the school could only afford to buy at most three keypunches. The purchase of keypunches is likely to cause a congestion problem similar to the one being experienced with the terminals. (The problem centers around the fact that only one student can use the keypunch at a time.) Also, air conditioning costs for the keypunches will result.

An experiment was run, and it was determined that it took almost ten times longer to mark cards than to keypunch them, but that more students could prepare cards in a given length of time if they could all mark them than if they had to wait for the keypunches. Indeed, it takes a good deal of time to code a 25-line program on mark-sensed cards. Program length is not expected to exceed 20 lines per program; and there are no more than 25 questions to be asked in any simulation which would be run in batch form.

The research going on in the card reading field was examined, and it was discovered that readers exist that can read handwritten or handprinted cards, but that the cost of these devices was much too great to be considered at this time.**15

Based on the above findings, it would seem reasonable to conclude that mark-sensed cards would be the best alternative to take. Providing a keypunching capability along with the mark-sense operation seems like an extravagant and unnecessry frill.

If it is decided that mark-sensed cards are the way to go, then careful consideration should be given to the card layout and design. Fewer marks should be required to code the digits (0-9) and the letters which frequently appear in the programming language statements being used, than special and infrequently used symbols such as :,%, and !.

CONCLUSION

The formulation of procurement policy is not an easy or simple task. There are many questions to be dealt with and problems to be resolved. Without some structure upon which to base policy decisions, the resulting system has no hope for any kind of consistency or direction.

The recommended structure upon which procurement policy decisions should be based employs a system performance model relating system output to system needs, demands, goals, and costs. Separate factors have been identified which link the system output to each of these system components, and the specific attributes of each of these factors have also been examined in the context of a CAI setting.

The laborious and difficult tasks of researching different types of products, examining competitive services, and making final decisions on which ones to purchase and which ones to reject are only the final stages of the procurement process. The initial stages of that process include addressing the topics listed under each of the system performance factor headings - fidelity, responsiveness, effectiveness, and efficiency. After these issues have been examined, a closer comparison of the costs, tradeoffs, and implications of possible procurement policy decisions can be made.

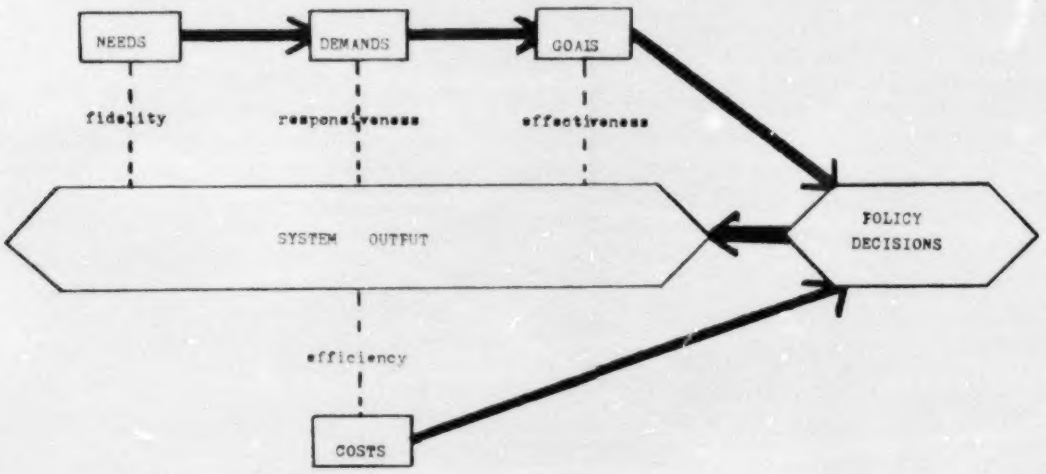
Complex and extensive relationships exist between the various system performance factors, and many decisions will effect two or more of these factors in contradictory ways. The objective of the system performance model is to provide the policymaker with a means to resolve the conflicts and to minimize their presence by identifying possible problem areas before decisions are actually made. Of course, each system will have its own unique and overriding concerns, so each policy decision will have to be based upon how those concerns are met, and how well the goals set for the system are fulfilled. In all systems, however, careful consideration should be given as to how every decision might effect each factor related to the system's performance.

The flexibility, compatibility, and expandibility of the system should always be kept in mind, since CAI systems are continuously changing. The goals established for the system should also be periodically reviewed, since the needs and demands which precipitated them also change, and the system should strive to respond to the values and principles of those within it.

By following the preceeding guidelines, if a system does receive adverse criticism, the problem area can be localized relatively easily, and emphasis on certain factors can be adjusted to resolve the conflict situation if it is determined that a change is appropriate. Such an evaluation scheme would be difficult to establish if the factors which regulate the system's performance were not clearly understood, outlined, and examined before procurement policy decisions were actually formulated.

The key, therefore, to formulating procurement policy is the examination and constant reevaluation of the system performance factors identified. The relative priorities of the various system components will dictate the direction that the procurement policy decisions should take. The system performance which results from following the recommended guidelines fulfills the needs of those in the system, satisfies the demands placed upon the system, and achieves the desired goals of the system with a reasonable and realizable cost.

Figure 1: Framework for Viewing System Performance



Basic components of the system.

Areas affected by the components of the system.

Indicates the direction of flow through which the policy formation process normally proceeds.

Identifies the factors which relate the components of the system to the system output. When trying to determine system performance, each of these factors, along with the system output, need to be taken into account.

FIGURE 2

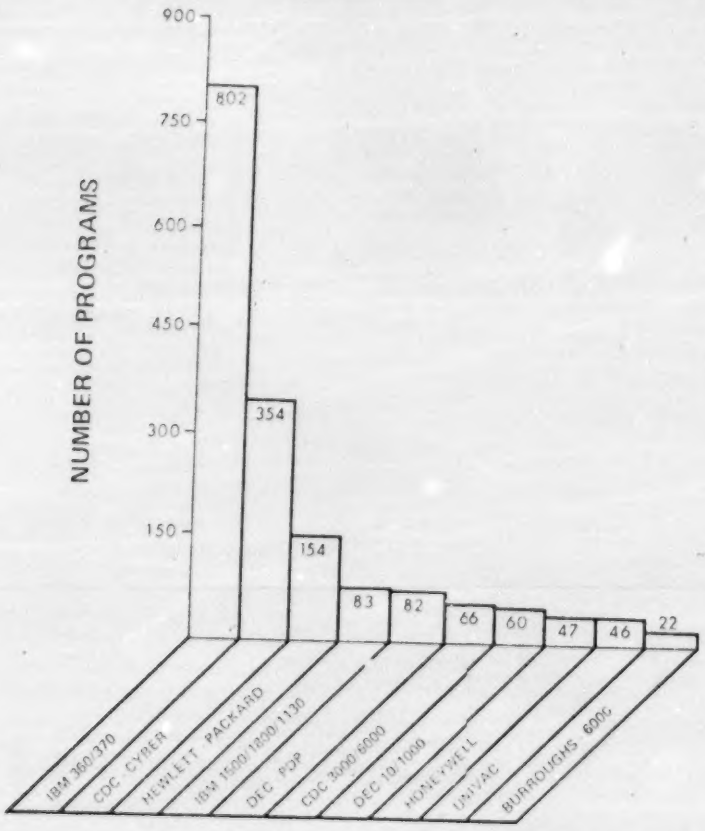


FIGURE 3:

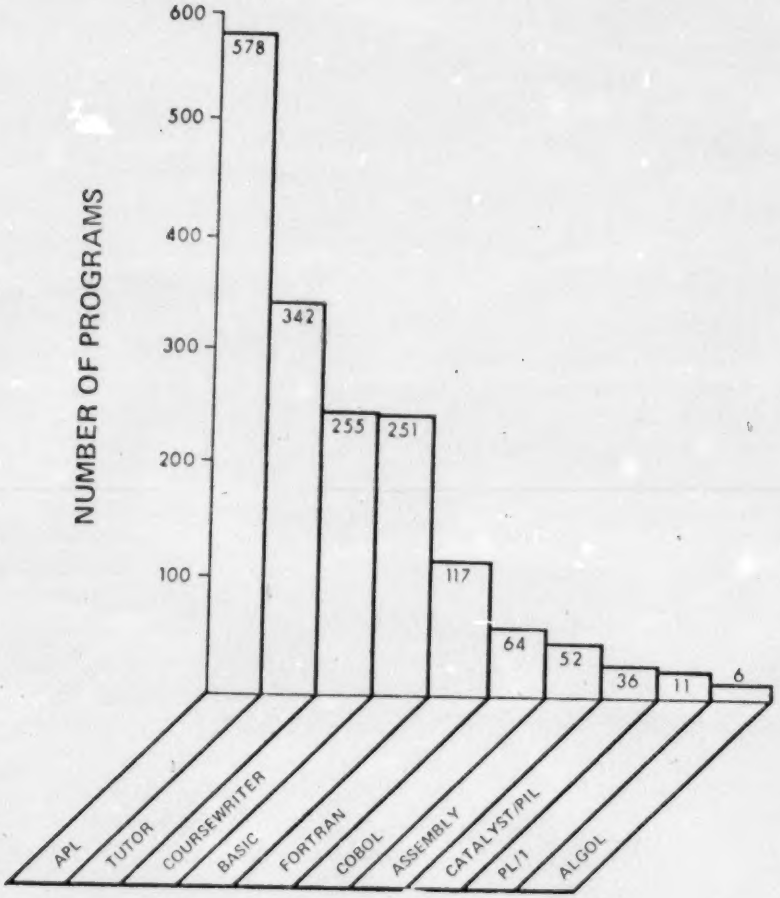
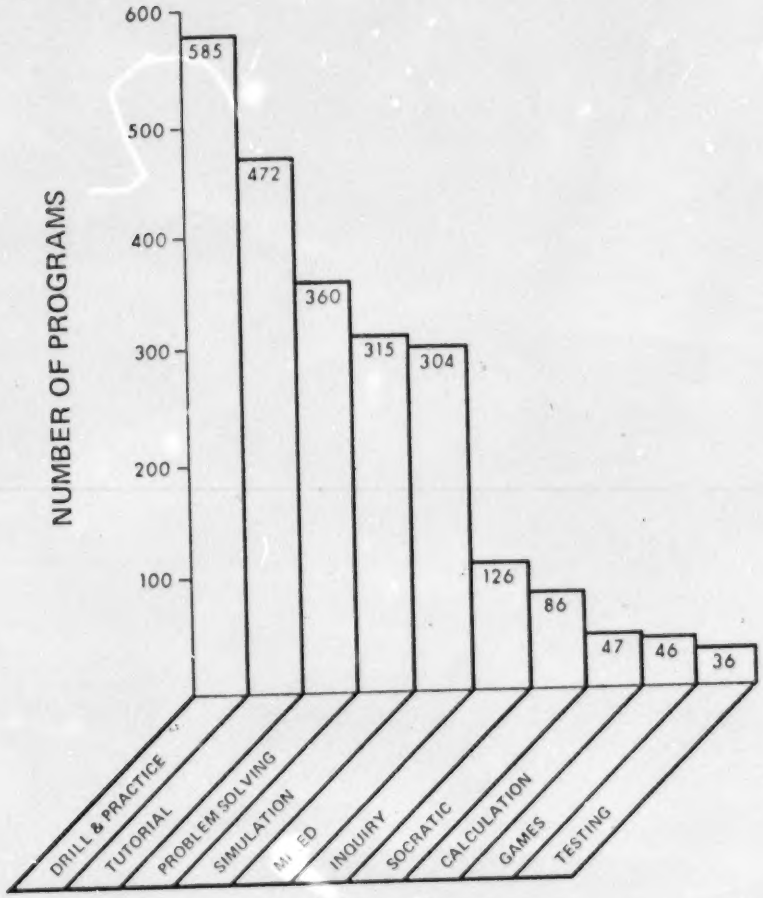


FIGURE 4:



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2 Coombs, Fred S., lecture given in Educational Policy Studies 303 class, University of Illinois, 1974.

3 The description of the general system performance model, as well as the general discussion of the four system performance factors are based on: Coombs, Fred S. and Gunther Lüschen, "System Performance and Policymaking in West European Education: Effectiveness, Efficiency, Responsiveness, and Fidelity," International Review of Education, 1976.

4 The various characteristics which are considered under each of the four system performance factors are primarily based upon guidelines set forth in both: Post, Dudley L., ed., The Use of Computers in Secondary School Mathematics, 1970. Scott, Robert H., "Planning for Computer Resources," Educom, Volume 10, Number 2, Summer, 1975.

However, some of the characteristics are taken from other works listed in the bibliography, while the remainder have been identified by the author through his experiences while managing and participating in the formulation of procurement policy for the CAI system in High School District 214, Mount Prospect, Illinois.

When the author began his work in district 214, the CAI system was centered around a timeshared HP 2000F system (capable of simultaneously supporting batch processing). The system was shared among 8 high schools and two libraries, and was capable of serving up to 24 users at a time (all of the users were connected to the system over phone lines). By the time the author left the system (1 year later), the system had been expanded to an HP2000 ACCESS system, capable of serving up to 32 users at the same time. During the transition process, many procurement policy decisions involving numerous aspects of the system had to be formulated; the difficulties encountered and the resulting successes and failures, are the basis for the contentions made by the author in the sections dealing with considerations related to procurement policy.

5 Articles have been written on the use and effectiveness of computers in reading programs, both for special education and standard curriculum students. The following works are good sources to consult for obtaining information on various reading projects: Atkinson, R. C., "Cost and Performance of Computer Assisted Instruction for Education of Disadvantaged Children," Education as An Industry, National Bureau of Economic Research, 1972. Atkinson, R. C. and J. D. Fletcher, "Evaluation of the Stanford CAI Program in Initial Reading," Educational Technology, Journal of Educational Psychology, Volume 63, Number 6, 1975, pp. 597-602. Atkinson, R. C. and J. D. Fletcher, "Teaching Children to Read with a Computer," The Reading Teacher, Volume 25, 1972, pp. 319-327. Binter, Alfred R., John J. Diabal Jr. and Leonard N. Rise, Readings on Reading, International Textbook Company, 1969, pp. 511-516. Beery, Althea, Thomas Barret and William R. Powell, Elementary Reading Instruction: Selected Materials, Allyn and Bacon, Inc., 1974, pp. 423-437 and 507-510. CERL Report, Plato Elementary Reading Curriculum, University of Illinois, Urbana: Illinois, 1974. ERIC materials, A Comparison of Teacher and Computer Prepared Individualized Reading Prescriptions, ED 119 117, and A Comparison of Reading and Vocabulary Achievement of Elementary Students Taught with Two Reading Teaching Methods, ED 117 670. Gross, Dr. Susan, Martha Luke Carr and Sally Mitts Rouse, Matteson 4-Dimensional Reading Project, ESEA Title III, 1974. Handler, Kenneth, "The Computer Comes to the English Classroom: Computerized Monitoring of Pupil Progress in Reading," Educational Technology, Educational Technology Publications, Inc., November, 1975, pp. 34-35. Hoye, Robert E. and Anastasia Wang, Index to Computer Based Learning, Educational Technology Publications, Englewood Cliffs: New Jersey, 1973, pp. 491-504.

6 An important and often overlooked alternative to micro- and mini- computers for single user applications is the maxicalculator. A good discussion of maxicalculators can be found in: Doring, Richard and Bruce Hicks, "A Detailed Comparison of Maxicalculators," The Illinois Series on Educational Applications of Computers, Number 6, 1976. Doring, Richard and Bruce Hicks, "Maxicalculators for the Whole School," The Illinois Series on Educational Applications of Computers, Number 5, 1976.

7 The classification categories are primarily based upon languages classifications given in: Post, Dudley L., The Use of Computers in Secondary School Mathematics. The placement of the various languages into specific categories was done by the author.

8 The figures are taken from: Keasler, Greg P., "Some 'Facts' About CAI: 1976 in Depth," Research and Information Report, University of Alberta, 1976. The basis for the information shown on the figures is: Wang, Anastasia, ed., Index to Computer Based Learning, Instructional Media Laboratory, University of Wisconsin, 1976. It must be emphasized that these kinds of figures provide only a sampling source of information (which is obtained on a voluntary basis). Hence the data is certain to be biased and somewhat in error, and should be used with caution. Inaccuracies, omissions, exaggerations, and misinterpretations on the part of the information suppliers should all be acknowledged, and the data presented should be used only as a guide for identifying possible trends in the CAI field. By no means should such figures be considered authoritative or complete.

9 Privacy and security issues in CAI systems (as well as many other kinds of systems), are important to consider when making decisions. The issues are too complex and varied to be discussed here. However, articles and books in this area do exist in the literature, and a good bibliographic source to begin with for works on security and privacy is: Hoffman, Lance J., Security and Privacy in Computer Systems, John Wiley and Sons, Inc., University of California, Berkeley, California, 1976.

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For federal rules and regulations regarding privacy and security of student record information, a starting point is the 'Privacy Rights of Parents and Students' article which is found in Appendix A of the Federal Register, Volume 40, Number 3, Part III, pp. 1208-1216. This article is put out by the Office of the Secretary of the Department of Health, Education, and Welfare; it was released on January 6, 1976 in Washington, D.C. Another source of pertinent information is 20 United States Code section 1232 (and the following sections).

For the State of Illinois regulations regarding privacy and security of student record information, examine the 'Rules and Regulations to Govern School Student Records' based on the Illinois School Student Record Act of 1975, and filed pursuant to chapter 122, article 50, of the Illinois Revised Statutes, 1975 (which became effective March 24, 1976). These regulations were established by the State of Illinois State Board of Education, from the Illinois Office of Education, under the direction of Joseph M. Cronin.

10 Gear, C. William, Computer Organization and Programming, McGraw-Hill Book Co., 1974, p. 238.

11 Brandon, D. H., 'Computer Acquisition Method Analysis,' Datamation, September, 1972, pp. 76-79.

12 Ibid, p. 77.

13 Proceedings of Educom Fall Conference, Policies, Strategies, and Plans, Educom, 1975, p. 28.

14 The concept of using computers for the whole school has been strongly advocated by William F. Goddard. A discussion of his ideas can be found in: Goddard, William F., 'Computer Technology for the Whole School,' Journal of Educational Data Processing, Volume 6, Number 2, 1969, pp. 109-120. Goddard, William F., 'Computers and the Whole School,' talk for a computer mathematics workshop at the University of Illinois in Urbana, November, 1971. Goddard, William F., 'The Small Computer and the Brand New Mathematics Teacher,' talk for a computer mathematics workshop at the University of Illinois in Urbana, November, 1971. Goddard, William F. and Bruce Hicks, 'Applications of Computers in the Whole School-Five Examples,' The Illinois Series on Educational Applications of Computers, Number 1, March, 1975. Hicks, Bruce, William F. Goddard and Linda Crider Keasler, 'Students: Where the Action Is!,' The Illinois Series on Educational Applications of Computers, Number 3, August, 1975.

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